Section 1
Summary and Conclusions

The purpose of this project is to determine the feasibility and usefulness of an economic analysis of the beneficial outcomes of water quality improvements that should result from upgrading sewage treatments plants (STPs) and from combined sewer overflow (CSO) controls. This report uses Boston Harbor, Boston, Massachusetts, to serve as a case study which demonstrates the application of a variety of benefit estimation techniques in order to develop a range of benefit values associated with the uses of the Harbor which would be affected by the various pollution control treatment alternatives. It contains pertinent data and computations to demonstrate the application of the techniques. This report may also serve as an Appendix to the EPA's Marine CSO Handbook, which states can use as an example of how to perform benefit analysis. Where feasible, the study provides dollar estimates of the economic benefits of the treatment alternatives for the two primary benefit categories (recreation and commercial fishing) as well as for other relevant benefits.

The STP treatment options considered here include upgrading from primary to secondary treatment and upgrading the existing primary treatment with an ocean outfall. One of the STP options considered follows from the legal mandate of the 1972 and 1977 Clean Water Act and Amendments, the Environmental

Protection Agency (EPA) standards and procedures for the treatment and disposal of municipal wastes. These regulations call for treatment at the secondary level (which includes more BOD and SS removal in addition to basic primary treatment) and a cessation of sludge disposal in the ocean.

The second STP option is an ocean outfall in conjunction with upgrading existing primary facilities. Plans have been made by the Metropitan District Commission (MDC) to repair and rehabilitate the STPs so that they will function properly at an upgraded primary treatment level. In addition, the MDC has applied for a variance under section 301(h) of the Clean Water Act from secondary treatment requirements. The application is based on an improved discharge whereby the two existing plants will improve their operation Of primary treatment, and effluent will be discharged at an ocean outfall in Massachusetts Bay via a tunnel 12.1 km (7.5 miles) from Boston Harbor. Since the initiation of this study, the proposed ocean outfall has been tentatively denied by the EPA Administrator (in June, 1983).

The selection of these options does not constitute endorsement of these proposals over other STP options, nor is this study a part of the formal 301(h) evaluation efforts. Rather, since the purpose of this study is to determine the feasibility and usefulness of an economic analysis of the beneficial outcomes of improved water quality, the two STP options are analyzed here as representative of the options under consideration at the time the study was initiated.

The CSO control options are derived from studies done for the Massachusetts District Commission as well as studies done for the town of

Quincy. They include control of pollution due to combined sewer overflows, stormwater discharges and dry weather overflows all of which contribute significantly to the CSO problems in the Boston Harbor area.

Boston Harbor is surrounded by a major urban center and, despite its serious water quality problems, provides the setting for many and diverse water uses including a fishing and shipping port, recreational boating, swimming and beach activities, shellfishing, finfishing, and, especially recognized in recent years, an aesthetic focal point for commercial, residential and recreational activities. Figure 1-1 shows the geographic features of the study area.

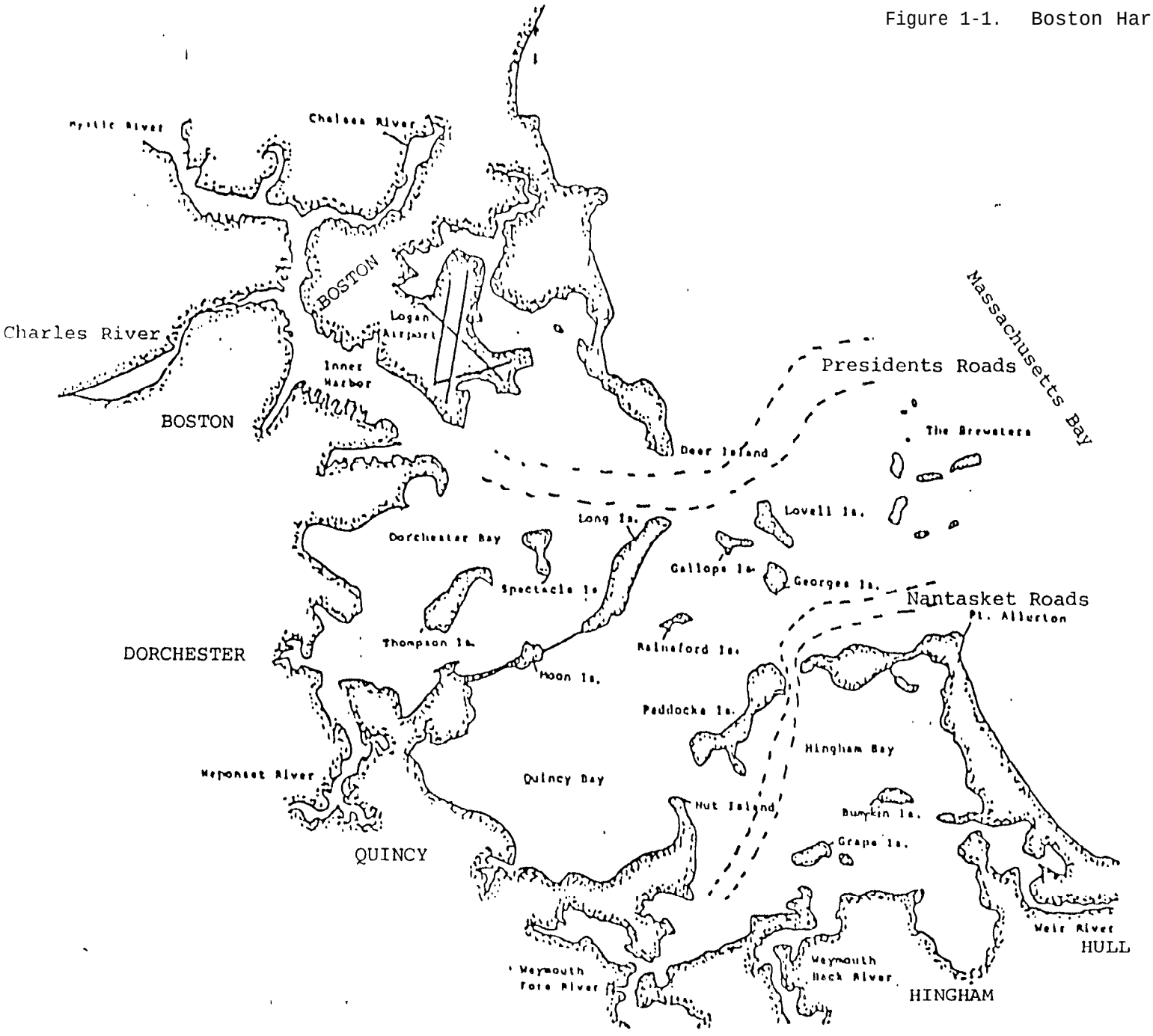
Due to the complexity of the situation, the constraints of the data, and the evolving nature of benefits analysis the results of this study should be viewed with caution. Every effort is made to assess the reliability of both the data and methods used. In the individual chapters of the report specific sections on the limitations of the analysis are provided.

This chapter provides a brief overview of the treatment alternatives, receptors, benefit categories, and benefit methodologies. A comparison of the benefits and costs of the alternatives is presented and the results of the study summarized.

1.1 Pollution Sources

Two major sources of pollutant loadings to Boston Harbor are 1) the Nut Island and Deer Island Sewage Treatment Plants (STPs), owned and operated by

Figure 1-1. Boston Harbor Study Area

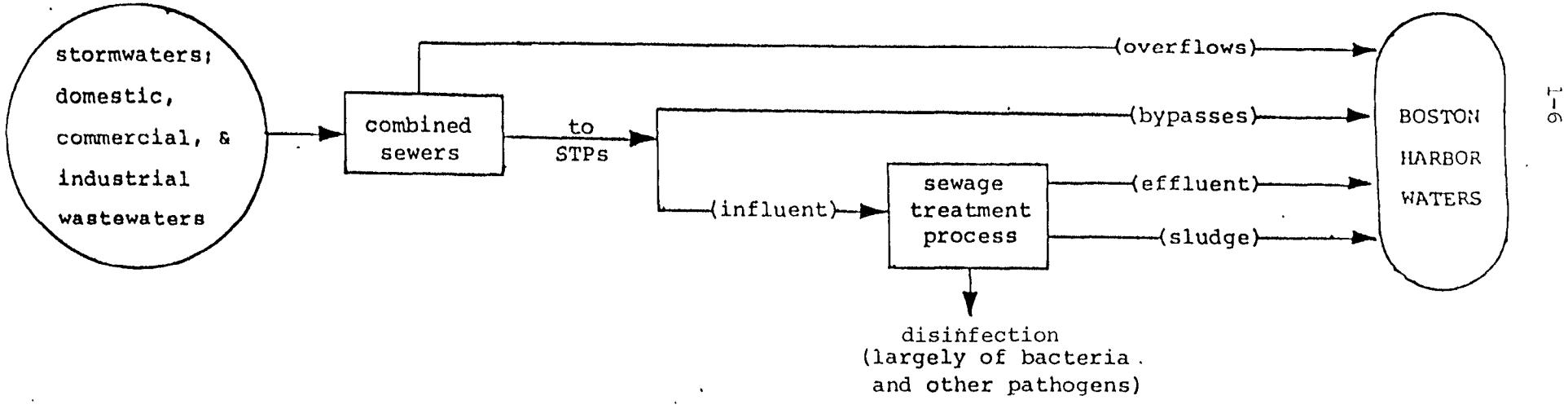


the Massachusetts Metropolitan District Commission (MDC), and 2) the combined sewer overflows (CSOs) located along the Harbor shoreline. The pollutants which are released from these sources serve as parameters for describing the environmental condition of the waters of Boston Harbor. Figure 1-2 is a schematic presentation of how the pollutant loadings enter the harbor from these sources. The following water quality parameters are considered in this report:

Parameter	Reason for Consideration
Coliform (fecal and/or total)	important criteria for swimming and shellfishing needs; indicator of domestic sewage pollution
BOD (biochemical oxygen demand); SS (suspended solids); oil and grease	conventional pollutants; standard wastewater characteristics
Heavy metals and toxics (copper, mercury, nickel, etc.)	potentially dangerous to aquatic life

Once these pollutants are released into the Harbor, they mix with ambient waters, and can seriously compromise water quality and, consequently, adversely affect the ecological habitat, recreation, aesthetic, and commercial fishing activities, and personal health. The heavy metals and other toxic pollutants affect the functioning of Harbor marshlands and influence the abundance and diversity of shellfish and finfish in the waters. The mechanisms and effects as related to levels of pollutant control are not known, however. Thus, this report presents information on current loadings of toxic pollutants from the STPs and qualitatively describes the ecological habitat and potential effects for these pollutants.

Figure 1-2. Schematic of Sources of Pollutant Loadings to Boston Harbor



Forty-three towns and cities in the Boston Metropolitan area belong to the Metropolitan Sewage System and send their domestic, commercial and industrial wastewater to the two sewage treatment plants for treatment and disposal (see Figure 1-3). At present, both plants are designed to carry out primary treatment which is essentially a screening , sedimentation and chlorination procedure. The treated effluent and concentrated, digested sludges are then discharged into the Harbor. System malfunctions are common, however, resulting from such factors as outfall pipe deterioration, inadequate holding capacity and lack of normal required maintenance due to, among other things, difficulties in obtaining funds for repairs and suitable replacements for malfunctioning components. As a result, the two STPs have not been functioning properly in accordance with their designs, leading to raw sewage bypassess directly into the Harbor, improperly timed sludge releases, sewer backups from the STPs, and less than design-level treatment performance, all of which adversely affect water quality.

The two STP options consist of secondary treatment and upgraded primary treatment with an ocean outfall. The secondary treatment option includes more BOD and SS removal than the current primary treatment facilities and a cessation of sludge disposal in the ocean. The ocean outfall option includes repair and rehabilitation of the existing primary treatment facilities and discharge of the treatedeffluent into Massachusetts Bay by way of a tunnel from Deer Island. These two options were picked from the many proposals being studied at the time of this report as representative of the proposals and not as an endorsement of one proposal over another.

Figure 1-3. Area Served by the MDC Sewerage System

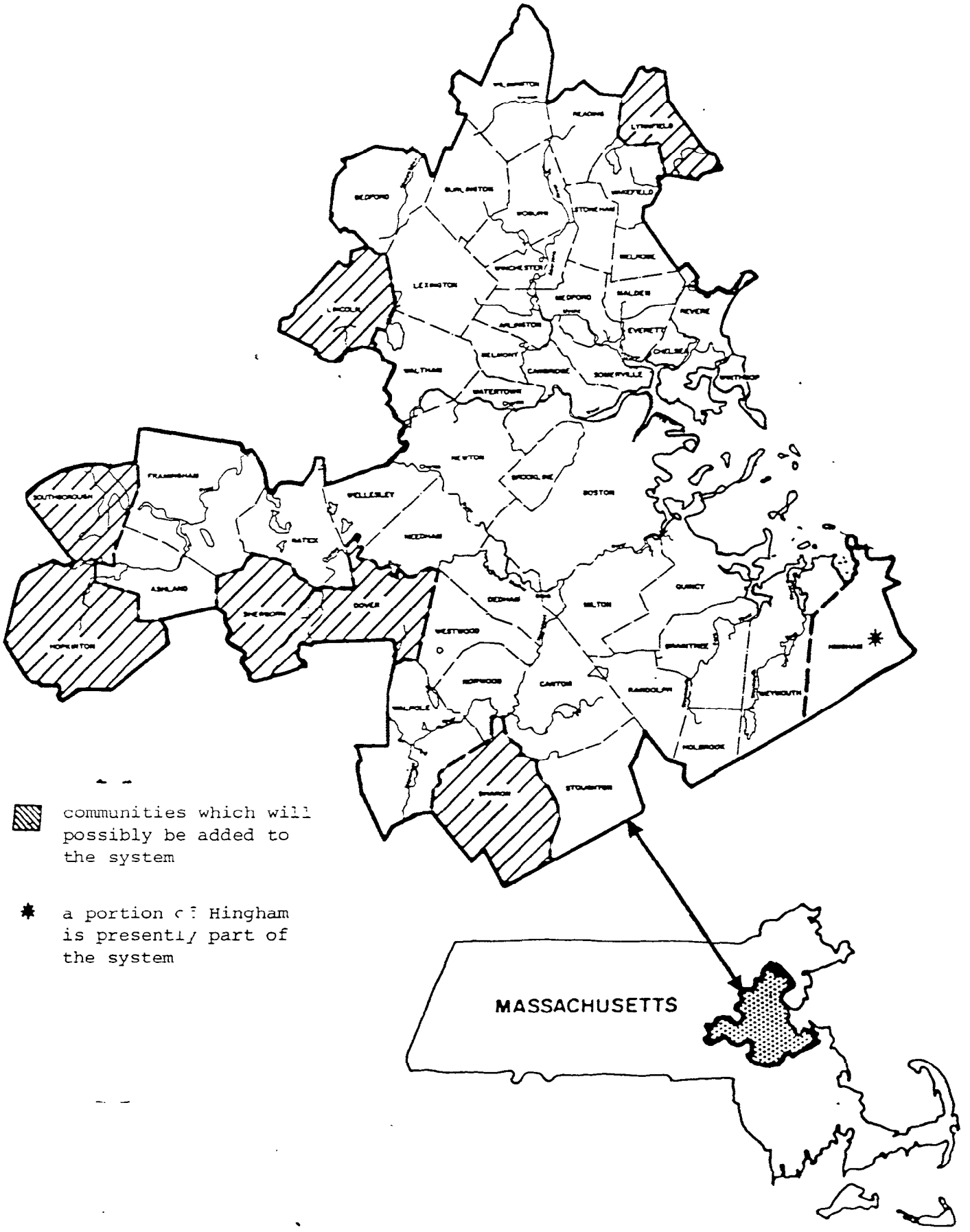


Table 1-1 compares the annual costs of the STP options and shows very approximate percentages for reductions in effluent pollutants, including BOD_5, suspended solids (SS), and metals, over existing concentrations.

In its effort to develop a comprehensive plan for CSO control in Boston Harbor, the MDC has designated four CSO planning areas: 1) Dorchester Bay, 2) Neponset River, 3) Inner Harbor (including Constitution Beach) and 4) Charles River Basin. The four areas are defined on the basis of existing water use and coastal use patterns. The water quality of all four planning areas is compromised by pollution from combined sewer overflows (CSOs), stormwater discharges, and dry weather overflows (DWOs). Storm-related combined sewer overflows vary in duration and frequency. DWOs, caused by sewer blockages and other malfunctions, are continual discharges of sanitary wastewater and are considered by the MDC to be the single most important source of pollution in Boston Harbor. They have thus been included in all the CSO plans even though they are not officially classified as CSOs under federal regulations. Combined sewer overflow outlet locations are shown in Figure 1-4.

Another source of pollutant loadings to Boston Harbor is the Quincy storm sewers. The Quincy storm sewers discharge waters with fecal coliform, BOD and SS concentrations that are higher than levels expected from storm water runoff. Storm water contamination can result from cross-connections between sanitary and storm drains, due to broken pipes and exfiltration from sanitary sewers in disrepair, and, possibly, illegal "tie-ins" to the storm sewer system although the latter has not been documented in Quincy. These present problems similar to the DWOs in Boston which have been included in the CSO plans. The Quincy storm sewers lie outside the MDC study area of

Table 1-1. Costs and Potential Reductions in STP Effluent Pollutants for the STP Options (Millions 1982$)

Wastewater Treatment STP Options	Costs			Approximate Percentage Reduction in Effluent Pollutants [b/]
	Annualized Capital Cost [a/]	Annual O&M Cost	Total Annual Cost	
Upgraded Primary With Ocean Outfall	74.9	22.0	96.9	[c/]
Secondary	85.8	45.2	131.0	60 - 80

a/ Based on 8 l/8 percent interest; 20 year period.

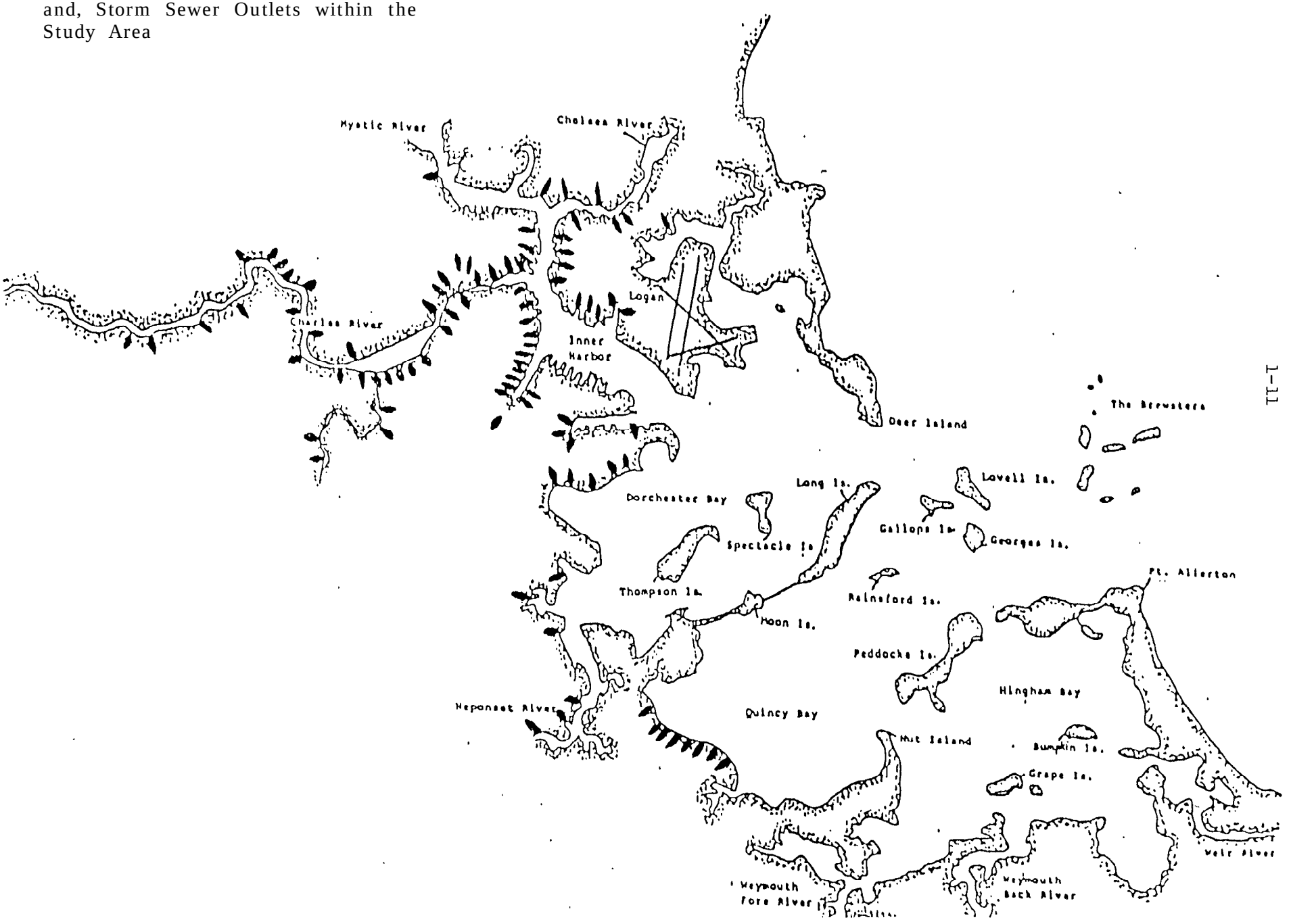
b/ Average potential reductions in effluent pollutants (BOD_5, SS and metals) over existing concentrations. Range is a very approximate estimate. For four heavy metals (cadmium, chromium, lead, mercury) the reduction would be about 30%.

c/ No effluent will be discharged in Boston Harbor. There will be increases of pollutants in Massachusetts Bay, however. See Section 4 for details.

Source: See Tables 2-2 and 2-3, Section 2.

Figure 1-4

Location of Combined Sewer overflow and, Storm Sewer Outlets within the Study Area



concentrated CSOs. However , they have been included as an option for this benefit-cost study because they have a significant adverse impact on the water quality of Quincy's town beaches and Wollaston Beach, a large MDC operated beach attracting many visitors, located in Quincy.

Table 1-2 shows the annual costs of the CSO options along with the approximate percentage reduction in pollutant loadings, including fecal coliform, floatable and suspended solids and oil and grease. The top part of the table presents the four CSO plans as designated by the MDC. The bottom part shows the options used in the benefit-cost analyses in this study (for a detailed discussion of the CSO options see Section 3). The options as defined in the lower half of the table correspond more appropriately with the benefit estimates associated with the uses of the Harbor. For example, all the swimming and shellfishing uses affected by the CSOs (and therefore the corresponding benefits estimates) can be captured by including only the Constitution Beach portion of the Inner Harbor Plan plus the Dorchester Bay, Neponset River, and Quincy Bay Plans. The CSO options in the table reflect incremental increases in annual costs.

1.2 Water Quality

Currently, the CSOs and STPs jointly affect some of the same harbor areas (see Figure 1-5). However, the CSOs generally affect the areas closest to the shore including the shoreline swimming beaches and fishing and boating areas near the shore. In comparison, the STPs have the greatest impact on water surrounding the STP outfalls and thus mostly influence the central parts of the harbor, particularly the Boston Harbor Islands. Beaches in the towns of Quincy, Weymouth, Hingham and Hull are also affected.

Table 1-2. Incremental Costs and Potential Reductions in Pollutant Loadings for the CSO Options

(Millions 1982$)

Treatment Alternative/ Receptor	Annualized Capital Cost a/	Annual O&M Cost	Total Annual Cost	Percentage Reduction in Pollutant Loadings b/
MDC PLANNING AREA DESIGNATION				
Inner Harbor				
a) Including Constitution	14.63	1.97	16.61	
b) Constitution only	0.04	0.01	0.05	50 - 99
Dorchester Bay	4.97	0.37	5.34	70 - 99
Neponset River	0.61	0.10	0.71	60 - 98
Charles River Basin	8.87	1.56	10.43	65 - 100
Implementation of all MDC designated CSO plans	35.44	4.00	33.39	50 - 100
STUDY AREA DESIGNATION				
Inner Harbor Constitution Beach only	0.04	0.01	0.05	50 - 99
Dorchester Bay/ Neponset River	5.59	0.47	6.06	60 - 99
Quincy Storm Sewers c/	0.27	-.02	0.25	60 - 99 a/
Above three plans combined	5.90	0.46	6.36	50 - 99
Charles River	8.87	1.56	10.43	65 - 100

a/ Based on 8 l/8 percent interest: 20 year period.

b/ From Contractor reports,

c/ Quincy plan is currently undergoing extensive revision.

d/ Assumed to be the same as Dorchester Bay Area.

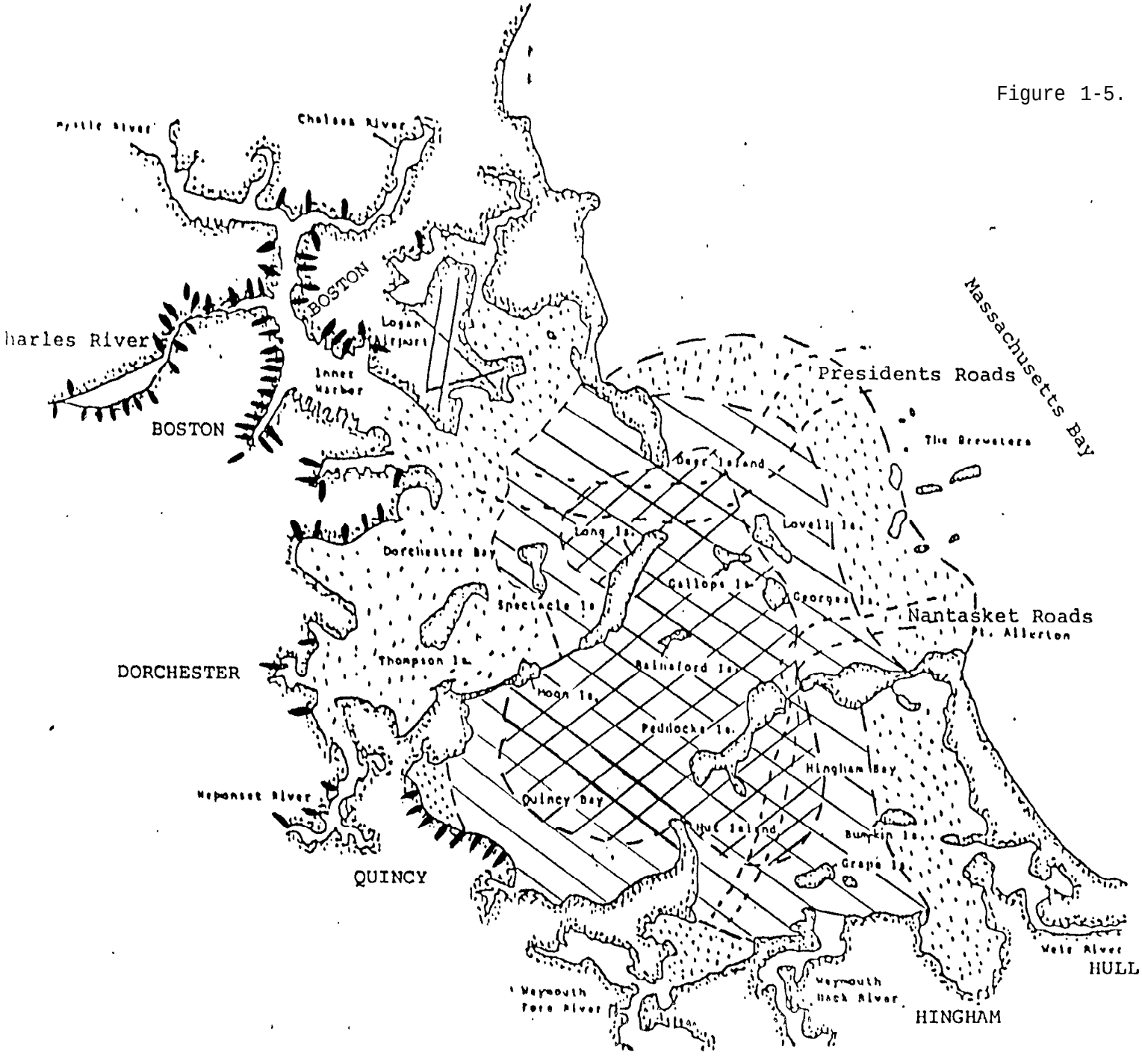


Figure 1-5. Current STP Dispersion Patterns and CSO Outlets

The various STP and CSO treatment options will reduce pollutant loadings, to the Harbor waters. The change in ambient water quality at various locations throughout the Harbor will depend on the change in reduced loadings but also on the dispersion pattern in the Harbor from the point of discharge to the receptor areas where recreation, boating and fishing take place. Several water quality models were used in the various contractor reports delineating the STP and CSO options. We use the results of these models to predict improvement in water quality related to percent reduction in pollutant loadings for the different treatment options at each receptor point in the study area. (See Section 4.) These estimates are presented in Table 1-3. The accuracy of the water quality models depends on both the data and methodologies available. Complexities due to currents, tides and weather make the transport and fate of pollutant discharges difficult to model. The results currently available preclude estimation of absolute changes in water quality but the relative percentage changes, as shown in Table 1-3, are adequate for the benefit estimation procedures used in this study.

1.3 Benefit Categories and Receptors

The benefit categories for which benefit estimates have been computed in this study have been determined by those uses of Boston Harbor that are affected by the pollution sources discussed above (STPs and CSOs). A term often used to describe areas or uses which are adversely affected by pollution sources and which would benefit from pollution abatement options is "receptors." The receptors or benefit categories in this study include recreation activities such as swimming, boating and fishing, commercial finfishing and shellfishing, the ecological habitat of the harbor and non-users who would be willing to pay, nonetheless, for pollution control

Table 1-3. Estimated Water Quality Impacts of the STP and CSO Treatment Options

Receptor Area	Percent Pollution Reduction by Treatment Option		
	Combined Sewer Overflow/ Storm Sewer	Deep Ocean Outfall	Secondary Treatment
Constitution Beach	50 to 80	5 to 10	0 to 5
Dorchester Bay	60 to 90	10 to 25	5 to 15
Quincy Bay	60 to 90	10 to 20	10 to 20
Hingham Bay	--	15 to 40	15 to 40
Cuter Harbor Islands	--	60 to 90	30 to 80
Brewsters Islands	--	-10 to -15	30 to 40
Nantasket Beach	--	-5 to -10	0 to 5
Massachusetts Bay	--	-35 to -45	15 to 20
Charles River	50 to 80	--	--

Note: Positive figures denote improved water quality. Negative figures denote degradation in water quality.

(intrinsic benefits). Alternative pollution control programs and the affected receptors are shown in Table 1-4.

The benefits of improved water quality resulting from implementation of pollution control options in Boston Harbor accrue to users and non-users alike, and are presented below with a summary discussion of specific benefit estimates. The techniques used in this report to measure benefits to society from implementation of pollution control plans are based on the theory of welfare economics and the concept of willingness to pay. This economic theory is founded on the principle that the "demand" for water quality is the sum or aggregate of how much individuals would be willing to pay to receive additional increments of improved water quality. Section 5 discusses the theoretical concepts, benefits categories and the various methodologies used to estimate benefit values for the different treatment alternatives.

1.4 Summary of Study Findings

A summary of annual benefits and costs for the different control scenarios is presented in Tables 1-5 through 1-7. The control scenarios include the MDC's recommended plans for CSO control and also the benefits of implementing CSO controls along with the STP options. The tables report the dollar estimates for the benefit categories and receptor areas for Boston Harbor. An indication of those benefits which were not monetizable in this economic analysis is also included to emphasize the full range of impact of these pollution sources and their consequent clean-up. One way to consider this potentially large non-monetizable portion from the point of view of the decision maker is an implicit evaluation of what they must be worth if it is decided to implement the controls by considering the difference between the

Table 1-4. Pollution Control Program and Receptors

Pollution Control Option	Predicted Percent Cleanup[a/]	Receptors/Benefit Categories
STP		
Ocean Outfall	10 to 30	Beaches: Weymouth, Hingham, Hull Boating and Fishing Shellfishing Intrinsic and Ecological
	-40 to -10	Beaches: Nantasket, Brewsters Islands Boating and Fishing Intrinsic and Ecological
Secondary	5 to 30	Beaches: Constitution, Dorchester Bay, Quincy Bay, Hingham Bay Shellfishing Intrinsic and Ecological
	20 to 70	Recreation: Outer Harbor Islands Boating and Fishing Intrinsic and Ecological
CSO		
Inner Harbor (includes Constitution)	70	Beach: Constitution Boating and Fishing Shellfishing Intrinsic and Ecological
Dorchester Bay and Neponset River	80	Beaches: Castle Island, Pleasure Bay, Carson, Malibu, Tenean Boating and fishing Shellfishing Intrinsic and Ecological
Quincy Storm Sewers	80	Beaches: Wollaston, Quincy Boating and Fishing shellfishing Intrinsic and Ecological
Charles River	70	Boating Intrinsic

a/ See Tables 4-2 and 4-3.

Table 1-5. Annual Benefits and Costs of Combined Sewer Overflow Controls
(Millions 1982$)

Pollution Control Option		Benefit Estimates by Category								Total Annual Costs[h]
		Swimming[b]	Recreational Boating	Recreational Fishing	Health[d]	Commercial Shell-Fishing[e]	Intrinsic[f]	Ecological	TOTAL	
Combined Sewer Overflows										
Constitution Beach	Range:	0.91-1.36	Not available for this option since boating and fishing are only calculated harbor-wide for combined STP and CSO options.		.005-.077	0-.005	Based on total recreational benefits. Not available for this option since boating and fishing benefits are only calculated harbor-wide for combined STP and CSO options.	Cannot be quantified but includes value of highly productive saltmarshes in Boston Harbor. These marshes in turn support many species of fish and invertebrates as well as animals, shorebirds and waterfowl.	0.92-1.44	0.05[h]
	Moderate:	1.14			.041	.003			1.18	
Dorchester Bay/ Neponset River	Range:	6.21-9.29			.021-.117	.001-.009			6.23-9.62	6.06
	Moderate:	7.75			.169	.005			7.92	
Quincy Bay	Range:	5.29-7.91			.086-1.275	0-.004			5.38-9.19	0.25-6.06[i]
	Moderate:	6.60			.681	.002			7.28	
Hingham Bay	Range:	-0-			-0-	-0-			-0-	
	Moderate:									
Massachusetts Bay/ Nantasket	Range:	-0-			-0-	-0-			-0-	
	Moderate:									
Entire Harbor (not including Charles River)	Range:	12.05-18.0[c]			.124-1.716	.001-.018			12.18-19.73*	6.36-12.17[h/i]
	Moderate:	15.02			.92	.010			15.95	
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*		3.19-7.24	10.43
	Moderate:		.51				4.71		5.22	
Four MDC CSO Plans (Constitution, Dorchester, Neponset, Charles River)	Range:	7.12-10.65	.05-.96		.027-.394	.001-.014	3.14-6.28*		10.34-18.3	16.54[h]
	Moderate:	8.89	.51		.21	.008	4.71		14.3	

[a] Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

[b] Swimming benefits based on conditional logit model. For Quincy, Hingham and Nantasket beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day value from logit model.

[c] Includes general recreation benefits at Boston Harbor Islands.

[d] Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

[e] Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

[f] Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

[g] Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

[h] Excludes cost of Inner Harbor CSO plan except for Constitution Beach portion; total annual cost of Inner Harbor CSO plan is $16.61 million.

[i] Cost estimates for Quincy storm sewers are still preliminary. High estimate is equivalent to costs for CSO control in Dorchester Bay.

Table 1-6. Annual Benefits and Costs of Combined Sewer Overflow Controls and Ocean Outfall Control Option (Millions 1982$)

Pollution Control Option		Benefit Estimates by Category: Swimming[b]	Recreational Boating	Recreational Fishing	Health[d]	Commercial Shell-Fishing[e]	Intrinsic[f]	Ecological	TOTAL	Total Annual Costs[h]
Combined Sewer Overflows and Ocean Outfall										
Constitution Beach	Range:	1.05-1.57			.008-.119			Potentially large beneficial impact on shoreline saltmarshes supporting fish and invertebrates as well as animals, shorebirds, and waterfowl. But negative impact on Massachusetts Bay with its finfish, lobster, crab and migratory whales and other species.	1.06-1,69	
	Moderate:	1.31			.064				1.37	
Dorchester Bay/ Neponset River	Range:	7.41-11.08			.032-.477				7.44-11.56	
	Moderate:	9.25			.255				9.51	
Quincy Bay	Range:	6.24-9.33			.146-2.15				6.39-11.48	
	Moderate:	7.78			1.15				8.93	
Hingham Bay	Range:	.215-.322			.003-.039				.22-.36	
	Moderate:	.269			.021				.29	
Massachusetts Bay Nantasket	Range:				(-.011) to (-.169)				(-.78) to (-.94)	
	Moderate:	(-.772)			(-.090)				(-.86)	
Entire Harbor (not including Charles River)	Range:	15.23-23.6[g]	5.39-12.13*	.30-7.91*	.189-2.67	.022-.124	10.1-21.8		31.23-68.23*	103.3-109.1[h,i]
	Moderate:	19.03	8.76	4.11	1.43	.064	15.9		49.29	
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*		3.19-7.24	10.43
	Moderate:		.51				4.71		5.22	
Four MDC CSO Plans (Constitution, Dorchester, Neponset, Charles River)	Range:									
	Moderate:									

a/ Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

b/ Swimming benefits based on conditional logit model. For Quincy town beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day values from logit model.

c/ Includes general recreation benefits at Boston Harbor Islands.

d/ Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

e/ Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

f/ Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

g/ Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

h/ Excludes cost of Inner Harbor CSO plan except for Constitution Beach portion; total annual cost of Inner Harbor CSO plan is $16.61 million.

i/ Cost estimates for Quincy storm sewers are still preliminary. High estimate is equivalent to costs for CSO control in Dorchester Bay.

Table 1-7. Annual Benefits and Costs of Combined Sewer Overflow Controls and Secondary Treatment Control Option (Millions 1982$)

Pollution Control Option		Benefit Estimates by Category: Swimming[b]	Recreational Boating	Recreational Fishing	Health[d]	Commercial Shellfishing[e]	Intrinsic[f]	Ecological	TOTAL	Total Annual Costs[g]
Combined Sewer Overflows and Secondary Treatment										
Constitution Beach	Range:	.98-1.46			.007-.096			Potentially large beneficial impact on shoreline saltmarshes supporting fish and invertebrates as well as animals, shorebirds, and waterfowl.	0.99-1.56	
	Moderate:	1.22			.051				1.27	
Dorchester Bay/ Neponset River	Range:	7.41-11.08			.032-.477				7.44-11.56	
	Moderate:	9.25			.255				9.51	
Quincy Bay	Range:	6.24-9.33			.146-2.15				6.39-11.48	
	Moderate:	7.78			1.15				8.93	
Hingham Bay	Range:	.215-.322			.003-.039				.22-.36	
	Moderate:	.269			.021				.29	
Massachusetts Bay/ Nantasket	Range:	-0-			-0-				-0-	
	Moderate:									
Entire Harbor (not including Charles River)	Range:	14.22-22.42[c]	6.46-14.57*	.75-9.49	.198-2.81	.022-.124	10.7-23.2		32.35-72.61*	137.4-143.2[h,i]
	Moderate:	18.32	10.52	5.12	1.51	.064	17.0		52.53	
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*		3.19-7.24	10.43
	Moderate:		.51				4.71		5.22	
Four MDC CSO Plans	Range:									
(Constitution, Dorchester, Neponset, Charles River)	Moderate:									

[a] Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

[b] Swimming benefits based on conditional logit model. For Quincy town beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day values from logit model.

[c] Includes general recreation benefits at Boston Harbor Islands.

[d] Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

[e] Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

[f] Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

[g] Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

[h] Excludes cost of Inner Harbor CSO plan except for Constitution Beach portion; total annual cost of Inner Harbor CSO plan is $16.61 million.

[i] Cost estimates for Quincy storm sewers are still preliminary. High estimate is equivalent to costs for CSO control in Dorchester Bay.

annual benefits as estimated and the predicted annual costs. One result that does stand out is that in addition to either secondary treatment or an ocean outfall the CSO problem needs to be addressed if full use restoration and health benefits are to be realized.

Some specific conclusions of this study include:

- Monetizable benefits

  -- Swimming benefits and all kinds of recreational benefits are the largest source of the monetizable benefits. In the commercial fishing category, we could only estimate shellfishing benefits. Nonetheless the recreational categories appear to be especially important for urbanized areas such as Boston Harbor where local population density and demand for nearby recreational opportunities are high.

  -- The geographic location of the pollution sources in relation to the receptor or benefit categories is an important factor in determining the type and level of benefits that will be generated by the different treatment options. In the case of Boston Harbor most of the recreation beaches are significantly affected by the CSO discharges and only moderately affected by the STPs. On the other hand, fishing and boating in Harbor waters are more affected by the STP discharges. In the case of fishing and boating, however, a further constraint is marinas and facilities--a constraint on increased participation in these activities not related to pollution control.

  --In our calculations the CSO options can be broken down by MDC Planning Area. For example, benefits related to the Dorchester Hay and Neponset River Plans and the Constitution Beach portion of the Inner Harbor Plan are summarized in Table 1-5. Also, Charles River and Quincy Bay can be isolated. This separation of plans is possible because of the geography of Boston Harbor and it would not be possible, necessarily, for all areas of the country. However, in our case the separation of plans can assist in the determination of the most effective way to allocate CSO control funds.

- Non-monetizable benefits

  -- Several categories include only a partial estimation of benefits. The commercial fishing category includes shellfishing only. Although up to 2.6 million pounds of lobster and 28.4 million pounds of fish are landed annually in the port of Boston, benefits related to this activity were not calculated because of the difficulty of knowing where the fish were caught and how they might be affected by the improved water quality.

-- Intrinsic benefits include aesthetic benefits and benefits such as existence and option value not directly related to use of the water resource. These are best evaluated by willingness-to-pay measures. As can be seen in the case of the Charles River (Table 1-5), they can be quite substantial. For the other areas in this study willingness-to-pay measures were not available, and the intrinsic benefit estimates were related to recreational activity which might not capture all non-user benefits.

-- A potentially large category of benefits not captured in this economic analysis is ecological benefits--benefits related to preservation and restoration of the harbor and bay habitats. The volume of pollutants controlled by the STPs is far greater than that controlled by the CSOs (approximately 30 times greater). Therefore, from an ecological perspective we need to be very concerned about the long term impacts that those heavy metals, toxics and other constituents in the STP effluents have on the harbor and bay habitats even though they are not immediately reflected or easily captured in the economic analysis. The CSOs are also of concern because of their proximity to highly productive saltmarshes along the shoreline.

-- In this study we have looked at uses of the Harbor waters which could be most directly analyzed within our economic analysis framework. This resulted in the exclusion of the Inner Harbor CSO Plan except for the Constitution Beach area. The Inner Harbor CSO control plan (reducing odor, floatables, and toxic substances) would include benefit categories of commercial use, aesthetics and ecological, none of which were monetizable. There are relatively few recreational uses in this area. Given the large amount of effluent discharged (about 11 billion gallons per year), the control costs are quite high and it would not appear that this CSO plan would be as important as the others in its overall impact.

- Costs

-- The costs for the CSO control options are estimates for preferred control alternatives. However, the costs for the Quincy Storm Sewers may not be comparable to the costs as used in the rest of the report. The Quincy cost study is still in the preliminary stages and not nearly as detailed as the other CSO plans. Thus, we show in the summary tables an upper range estimate equal to the CSO control costs for Dorchester Bay, its neighbor to the north.

As is clear from the discussion above, the benefit estimate numbers presented in Tables 1-5 through 1-7 should not be taken as especially

important or precise in themselves. They are approximations and represent means computed from ranges, sometimes wide ranges, that have been developed for each benefit category: they are the result of, for the most part, conservative assumptions: and they generally underestimate the benefit values of the treatment options. For instance, as discussed above, ecological benefits have not been included as they are considered non-monetizable (see Section 10). Recreational boating and fishing benefits (except for Charles River) have been computed only for the Harbor as a whole, since data was unavailable to break the totals down by option. The totals were included, however, to give an idea of the possible magnitude of these benefits. Despite these shortcomings, it is apparent from the conclusions that have been drawn that an economic analysis of the beneficial impacts of water quality improvements is feasible and is a useful tool for providing information to decision makers to facilitate improved policy decisions, especially where there is a choice to be made among various alternatives and a limit to the available funding.

1.5 Specific Benefit Estimates

Benefits accrue to households who recreate in, on or near the water, to consumers of commercial fisheries, to consumers who benefit directly and indirectly from the increased economic activity in the primary sector, and to non-users of Harbor waters, who derive intrinsic benefits. Each benefit category, estimation procedure, and benefit estimate are briefly described below.

1.5.1 Recreation

Benefits from increased recreational opportunities are the greatest of all the monetizable benefit categories. Benefits accrue to swimmers, boaters,

anglers and those who recreate near the water. Two major components of consumer surplus have been estimated which fully capture benefits from improved water quality: (1) increase in participation, and (2) increase in the price participants are willing to pay per visit for the improved quality of the recreational experience. The following is a brief summary of the three major recreation benefit categories considered in this study.

Swimming. A variety of benefit estimation methodologies were employed to estimate swimming-related benefits. These included: (1) using recreation studies to predict and value increases in participation; (2) applying a travel cost, conditional logit model to estimates gains in consumer surplus due to increased participation and increased satisfaction per trip: and (3) calculating consumer losses stemming from beach closings. Results from the travel cost model are the most accurate of all the methodologies because of the theoretical and empirical strengths of the logit model Benefits associated with the CSO control options are substantial: $18-19 million for swimmers throughout the Harbor area for a full plan of STP and CSO controls. About $15 million of this is related to CSO controls because of the Proximity of their discharges to the shoreline beaches. (See Chapter 6.)

Fishing and Boating. Fishing and boating benefits have been calculated only for the entire Harbor study area because of data limitations. Benefits for both these categories are substantial: $12 to 15 million for both activities for combined STP and CSO controls. (See Chapter 6.)

Boston Harbor Islands--All Recreation Activities. The Boston Harbor Islands are a unique recreation resource that will benefit from improved water quality resulting from the implementation of the STP treatment alternatives.

Recreational data was used to predict increase in participation in all Boston Harbor Island activities. Benefits total $1 to 3 million. (See Chapter 6.)

1.5.2 Health

Health benefits from water pollution abatement include willingness to pay to avoid swimming-related illnesses and shellfish consumption-related illnesses. Dose-response data were used to evaluate swimming-illness benefits. No such functions exist for consumption of shellfish, and thus these benefits were developed by assuming that a percentage reduction in shellfish-borne diseases is directly proportional to percentage reduction in the concentration of the fecal coliform in the water. Total health benefits from CSO and STP controls are about $1.5 million. They are lowest at Constitution Beach and highest at the Wollaston/Quincy beaches, which have the highest swimming attendance and are in close proximity to the Quincy storm sewers. Shellfish consumption benefits can only be linked to pollution reduction throughout the entire harbor. Benefits are small, from $0.001 million to $0.005 million. (See Chapter 7.)

1.5.3 Commercial Fisheries

Water pollution abatement in Boston Harbor would probably result in a reclassification of shellfish beds from grossly contaminated (closed beds) to moderately contaminated (restricted beds), thereby allowing increased shellfish harvesting with depuration. Moderate benefits are about $0.06 million for combined STP and CSO controls. (See Chapter 8.) These benefits do not include the sizable commercial catches of finfish and lobster. Current

annual value of these catches reaches $18 million. We were not able to calculate incremental annual benefits for this portion of commercial fishing benefits, however.

1.5.4 Intrinsic Benefits

Water pollution abatement is predicted to have an important effect on benefits which are not specifically related to actual water use, such as option, existence, and aesthetic values. Except for the Charles River, because of the lack of appropriate willingness to pay survey data which could be applied to the different treatment alternatives in the study area, intrinsic values have been estimated by assuming that non-user benefits are one-half as great as recreational user benefits. (See Chapter 9.) Moderate estimates for intrinsic benefits total $16-17 million.

1.5.5 Ecological Impacts

Pollution abatement might positively influence ecological processes in saltmarsh areas throughout the harbor. Although attempts have been made to estimate the economic value of marshlands by valuing the role of the marsh as a factor of production, and by estimating the cost of duplicating these functions, it was not possible to apply these results to the Boston Harbor study area. This is because the connection between the levels of pollution control, the subsequent reduction of pollutant loadings to the water column and the functioning of the marshlands is unknown for the harbor. Furthermore, the role of pollutants already in the sediments, that could be resuspended into the water as loadings are reduced, is not well understood at this time. Therefore, these benefits have been considered non-monetizeable. (See Chapter 10.)

The adverse ecological impacts believed to be caused by current and past levels of pollutant loadings include:

-- the alteration of benthic populations which may reduce the food supply, thereby resulting in a decrease in commercially valuable fish variety and numbers;

-- the accumulation of toxics by benthic fauna and then passage up the food chain where they pose a health risk to consumers (copper, mercury, PCBs, silver found in tissues of lobster and winter flounder);

-- bioaccumulation which can affect species reproduction, increase potential for disease (fin erosion in winter flounder associated with PCB contamination), and impair predator avoidance behavior which could result in reduced numbers and variety of fish.

Important commercial species that may be adversely impacted include lobsters, manhaden, cod, bluefish, striped bass and eels. Ecological benefits would accrue to the pollution control measures if the reduction in pollutant loadings caused reductions in the aforementioned adverse impacts.

The ecological benefits of the STP options may be larger because the volume of discharge is about 30 times as great as for the CSOs. However, the ocean outfall option will negatively impact some of the areas in Massachusetts Bay which include:

-- commercially valuable species such as tautog, cod, pollack, haddock, halibut, mackeral; and

-- migratory and endangered species such as whales, sea turtles, sturgeon and the Peregrine falcon.

1.5.6 Secondary Effects

Improving water quality will result in secondary effects from increases in economic activity generated in an area by direct impacts, such as commercial fisheries or recreation activities. A range of input and output multipliers were

applied to each benefit category to compute all secondary economic effects. Secondary effects cannot be linked to each pollution control option for every primary benefit category because some of the benefit categories, such as fishing and boating, could only be developed on a harbor-wide basis. We have chosen to refer to these values as effects, rather than benefits, because only under certain circumstances can secondary effects be considered benefits and the labor market analysis required for delineation and definition of these circumstances was beyond the scope of this case study. For these reasons we have calculated the different secondary effects, but have not included the dollar value in the summary of total pollution control benefits. (See Chapter 11.)

1.5.7 Charles River Basin

Benefits to instream, near-stream users and non-users of the Charles River were calculated by estimating increase in boating participation and by applying results from a willingness to pay survey. Boating benefits are small ($0.51 million) because all river acres in the Charles River Basin currently are used for boating and because user day values used to value this increase are moderate. The benefits of improving water quality along the Charles more accurately are measured by applying results of a willingness to pay survey, which captures benefits to users and non-users alike. Benefits calculated using this methodology are substantial: $4.7 million. Despite the large size of these benefits, they are approximately half of the estimated $10.43 million annual cost. of implementing the Charles River Basin CSO plan. (See Chapter 12.)

1.6 Guide to the Report

This chapter has summarized the features of the study area, the treatment alternatives and the benefit categories. It also has presented a brief analysis of the treatment options and a brief summary of study results and

conclusions. The specific STP and CSO treatment options are discussed in detail in Sections 2 and 3. Their effects on Harbor water quality are included in Section 4. Section 5 presents a brief introduction to the theoretical and methodological approaches used to measure benefits from improving water quality, and discusses the benefit categories applicable to this case study. The next six sections describe each benefit category and include benefit estimation methodology, data bases used in the analysis, benefit estimates, and limits to the analyses: Section 6, Recreation Benefits; Section 7 Health Benefits: Section 8, Commercial Fisheries; Section 9, Intrinsic Benefits: Section 10, Ecological Benefits: and Section 11, Secondary Effects. Section 12 presents a separate analysis of benefits from implementing the Charles River Basin CSO Plan.

Several Appendices follow the major text. Appendix A gives a more detailed view of STP treatment alternatives and their effects on Harbor water quality. Appendix B presents detailed calculations for the different methodologies used to estimate recreation benefits and includes a description of the major recreation sources used in this analysis. Appendix C explains how health benefits are calculated and Appendix D presents a step by step analysis of commercial fisheries benefits calculations. Appendix E summarizes calculations of recreation boating benefits from water quality improvement in the Charles River Basin.